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TEST RESULTS OF THE LUMINOSITY MONITORS FOR THE LHC*

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Abstract

The Luminosity Monitor for the LHC has been built at LBNL and will be operational in the LHC during the upcoming run. The device, a gas ionization chamber, is installed in the high luminosity regions (those dedicated to the ATLAS and CMS experiments) and capable to resolve bunch-by-bunch luminosity as well as survive extreme levels of radiation. During the experimental R&D phase of its design, a prototype of this detector has been tested extensively at the ALS, in RHIC as well as in the SPS. Results of these experiments are presented here.

INTRODUCTION

The luminosity measurements in the high luminosity points of the LHC are particularly challenging due to the extreme levels of radiation. Our team has designed a gas ionization chamber to operate in such an environment[1,2] and tested its prototype in existing accelerators. We present here the results of the tests made at the ALS, where using an electron beam we demonstrated the conceptual design and fundamental operation, at RHIC, where we compared the performance of this device with the existing luminosity monitors, and at the SPS, where we validated the model with a high energy proton beam.

EXPERIMENTS AND RESULTS

Luminosity Measurements in RHIC

ZDCs[3] are used at RHIC as the primary luminosity measurement. When the PHOBOS experiment was decommissioned, we had an opportunity to test a LUMI detector in a collider environment. In run 7 (100 GeV/c Au on 100 GeV/c Au), we placed the detector just between the first and second ZDC modules.

The chamber was operated at 8 atm with an Ar 94%, N 6% mixture. Due to the voltage rating of the connectors mounted in the prototype, we operated the chamber at 400 V, which did not optimize the speed of the signal at that pressure. The discriminated analog output from all four quadrants was recorded by the RHIC control system using scalers. Figure 1 shows the correlation between one of the LUMI quadrants and the ZDC scaler during a dedicated vernier scan. This scatter plot clearly shows a very good agreement between the LUMI and the RHIC ZDCs.

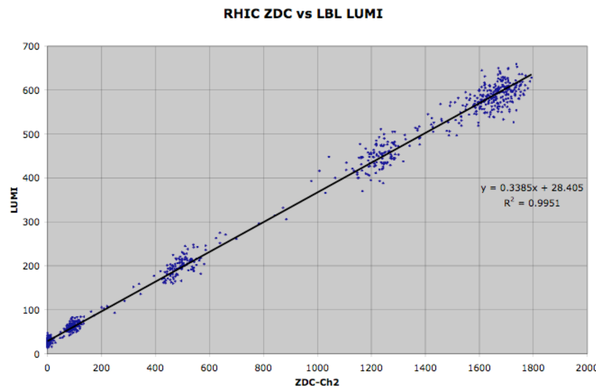

Figure 1: Correlation between the counts from LUMI quadrant 2 and the ZDC.

40 MHz resolution at ALS

The Advanced Light Source (ALS) at the Lawrence Berkeley National Laboratory provides a high-energy (1.5GeV) electron beam that can be used to test the detector. In order to demonstrate the 40 MHz operation of the detector, we used a dedicated fill pattern and an x-ray beamline. Using a special housing with a thin wall that allowed the photons to penetrate, we irradiated the chamber and compared its signal with that of a BPM. Figure 2 shows the comparison. An intensity scan showed good linearity with no sign of saturation even at signals much higher than expected in the LHC.

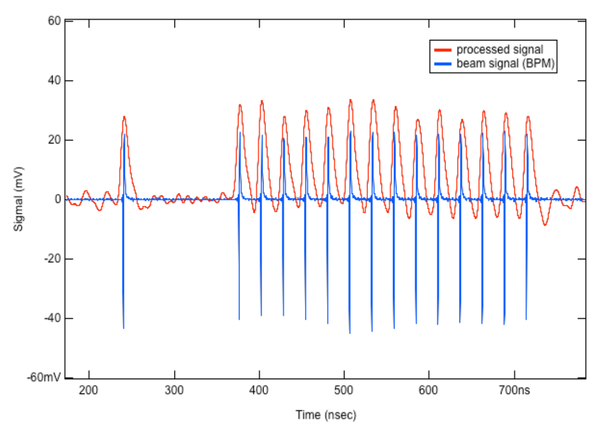

Figure 2: 40 MHz signal from the luminosity monitor chamber compared with an ALS BPM signal.

Position Resolution and signal speed at ALS

The ALS also provides a 1.2-1.5 GeV electron beam at the BTS (Booster-To-Storage ring) transfer line, operating in single bunch mode at 0.5 Hz. Here we mounted the

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detector on a 2 axis motion stage, and were able to scan the device while keeping the beam optics constant.

Integrating the incoming charge for every beam pulse we can normalize the signal from each quadrant with the beam current. Figure shows the result from the sum of all normalized voltages of the four quadrants.

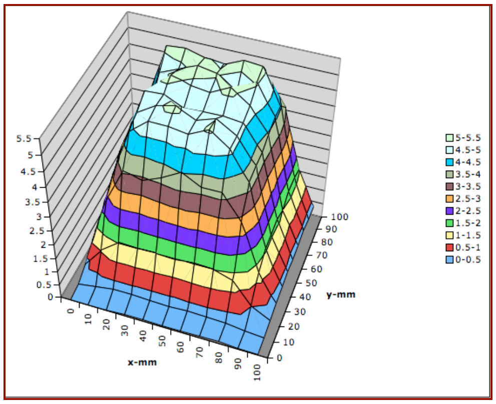

Figure 3: Sum of the response of all four quadrants normalized by the flux of electrons.

The figure shows that the size of the chamber is about 8 cm × 8 cm, which is the size of the LUMI monitor. The flatness at the top varies about 10%, mostly due to the shot-to-shot fluctuations of the ALS beam from the booster. As the beam is not measured shot-to-shot, this effect cannot be corrected.

In this setup we can also measure the position sensitivity by processing the signals from the four quadrants. For instance, in Figure 4 and 5 we plot the quantity:

$$\left[(A+C)-(B+D)\right]/\left[A+B+C+D\right]$$

These figures show the location at approximately x = 50 mm where there is equal sharing with halves (A+C) and (B+D). Similar plots occur when we do the same calculation in the Y plane. These results show how the four-quadrant design of the LUMI detector can be used to determine the position of the beam.

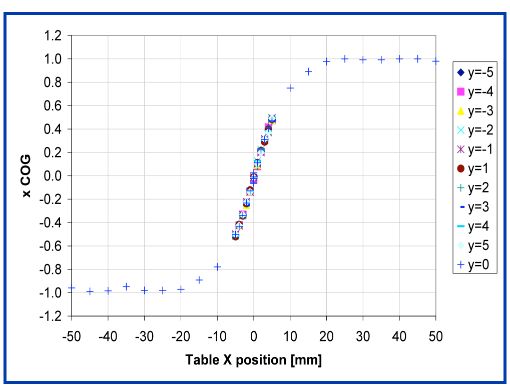

Figure 4: 2D differential sum of the four quadrants.

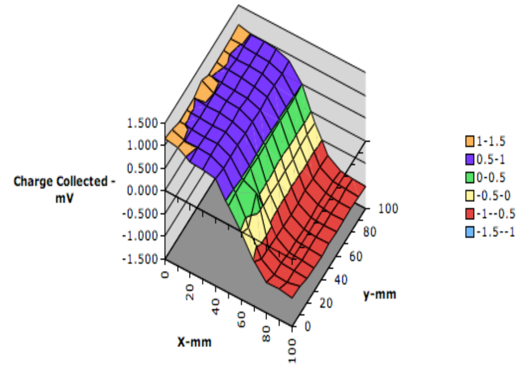

Figure 5: 3D differential sum of the four quadrants

In the same setup we could also complete a set of measurements to validate the model of the system. In particular, we verified the speed optimization, by scanning the bias voltage at a fixed pressure. Figure 6 confirms the estimated value of 200 V/atm, in this case at 2 atm.

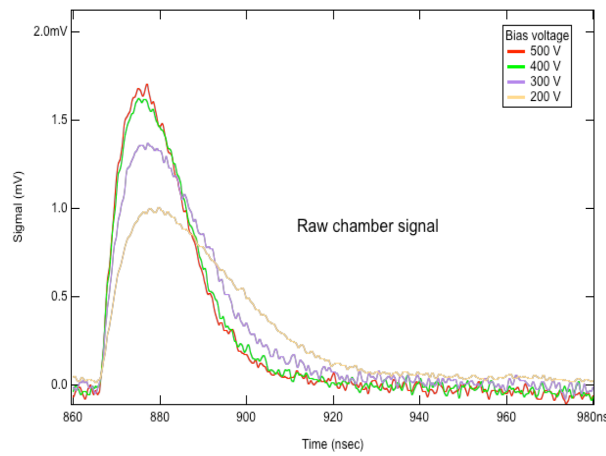

Figure 6: Bias voltage scan (20 ns/div)

Absorber Scan at the SPS

The fixed target area at the SPS, provided the opportunity to study device using a high energy beam and, in particular, the propagation of the hadronic shower in copper. This is important as the neutral products from the beam interaction at the LHC shower in the TAN absorber that contains the LUMI.

For this measurement, we used the 350 GeV proton beam extracted from the SPS and incident upon the chamber, which was operated again at a pressure of 8 atm. Like at the ALS, we mounted the system on a 2 axis stage, and could move the chamber so that the beam hit the center of a quadrant and the full shower was contained in that one sector. We triggered on an upstream scintillator and recorded the digitized waveform of each quadrant. The average maximum of the waveforms was calculated. The result of the data is shown in Figure 7. Each data point shows a different copper absorber thickness. The results show that the shower increases until 20 cm of copper absorber and then starts to decrease.

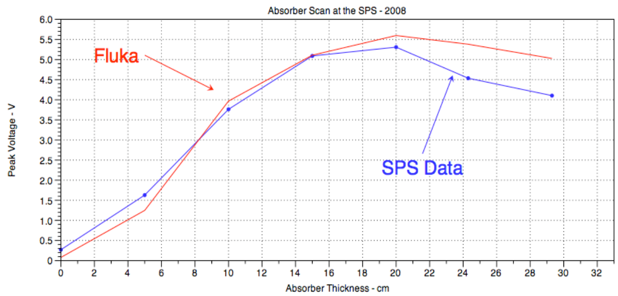

Figure 7: A plot of the average energy deposited in a quadrant versus the copper absorber thickness and compared with results calculated by FLUKA.

Modeling results

To compare these results, we used the Monte Carlo simulation program FLUKA[4], a general-purpose tool for calculating particle transport and interactions with matter. A picture of the model is shown in Figure 8. With this setup, we ran difference simulations for each of the copper block thicknesses. To compare with the SPS data, we used the nominal amplifier gain of 0.32 $\mu V/e^-$ and 9.72 ion pairs/(MIP•mm•atm). In addition, we factored that the chamber has 6 gaps of 1 mm each.

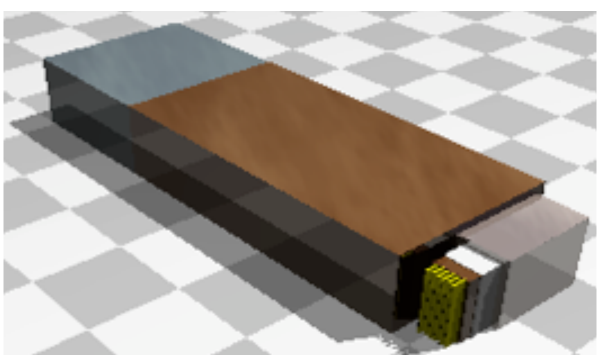

Figure 8: Representation of the LUMI detector in FLUKA.

The proton beam comes from the upper left. The grey area represents the air after the scintillator. The brown area shows the copper absorber. The LUMI chamber is cut away showing the 6 gaps (yellow elements). As shown in Figure 7, the comparison shows excellent agreement between the model and the simulation.

CONCLUSIONS

We have completed a set of experimental measurements that validate the design and expected performance of the LUMI detector. The good agreement between models and measured performance contributes encouraging results in preparation of the upcoming LHC run.

ACKNOWLEDGMENTS

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